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Albers

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(54) **VARISTOR IN BASE FOR MEMS MICROPHONES**

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(51) **Int. Cl.**

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B81B 7/00	(2006.01)
B81C 1/00	(2006.01)
H01L 23/525	(2006.01)

(52) **U.S. Cl.**

CPC ***H01L 29/84*** (2013.01); ***B81B 7/0012*** (2013.01); ***B81C 1/00341*** (2013.01); ***H01L 23/5252*** (2013.01); ***H01L 23/5256*** (2013.01)

(58) **Field of Classification Search**

CPC . H01L 29/84; H01L 23/5256; H01L 23/5252; B81B 7/0012

See application file for complete search history.

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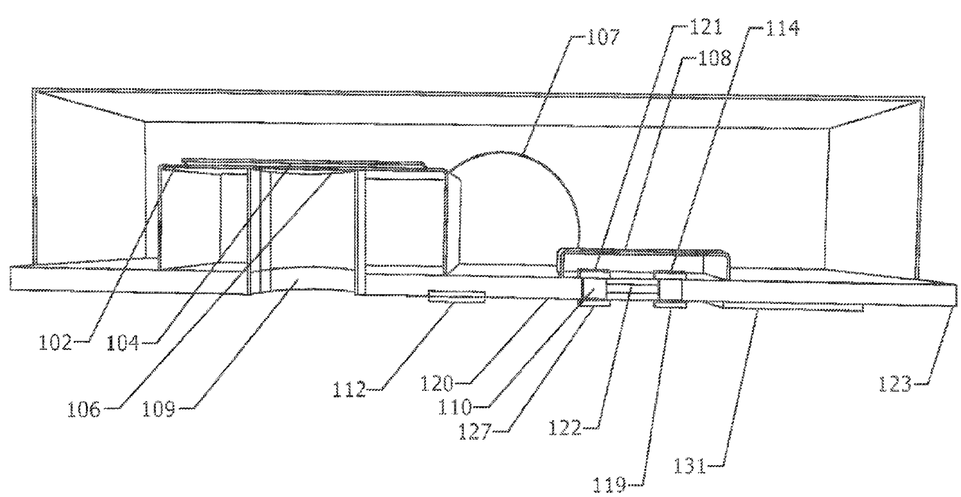
(57) **ABSTRACT**

A micro electro mechanical system (MEMS) apparatus includes a substrate. The substrate includes a first surface and a second surface. The first surface and the second surface are on opposing sides of the substrate. A programming contact pad is disposed on the second surface of the substrate. A MEMS device is disposed on the first surface of the substrate. An integrated circuit is disposed on the first surface of the substrate and electrically connected to the MEMS device and the contact pad. An anti-fuse region is coupled to the pad and to ground. When the anti-fuse region is not fused, a first electrical path exists from the programming contact pad to the integrated circuit. When the anti-fuse region is fused, a second electrical path is created from the programming contact pad to ground and the first electrical path is no longer available for programming purposes.

10 Claims, 6 Drawing Sheets



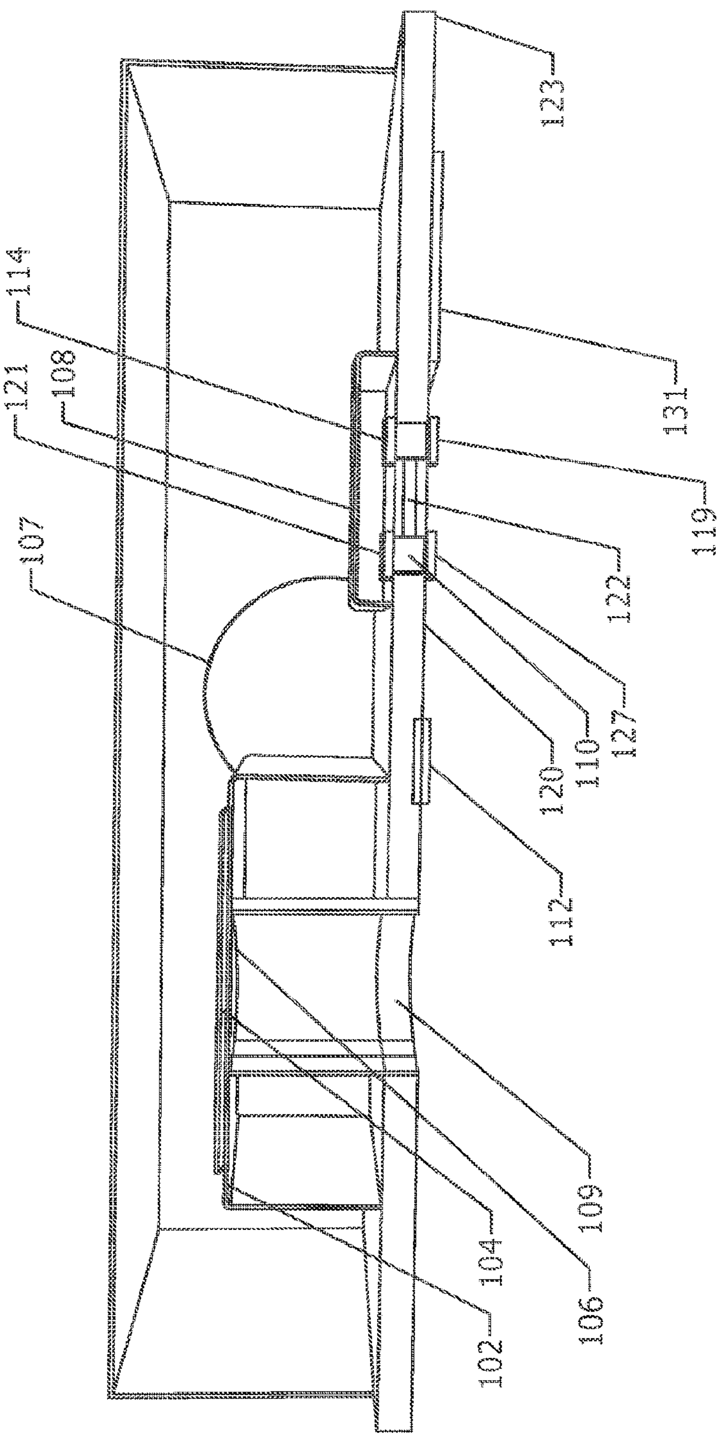


FIG. 1A

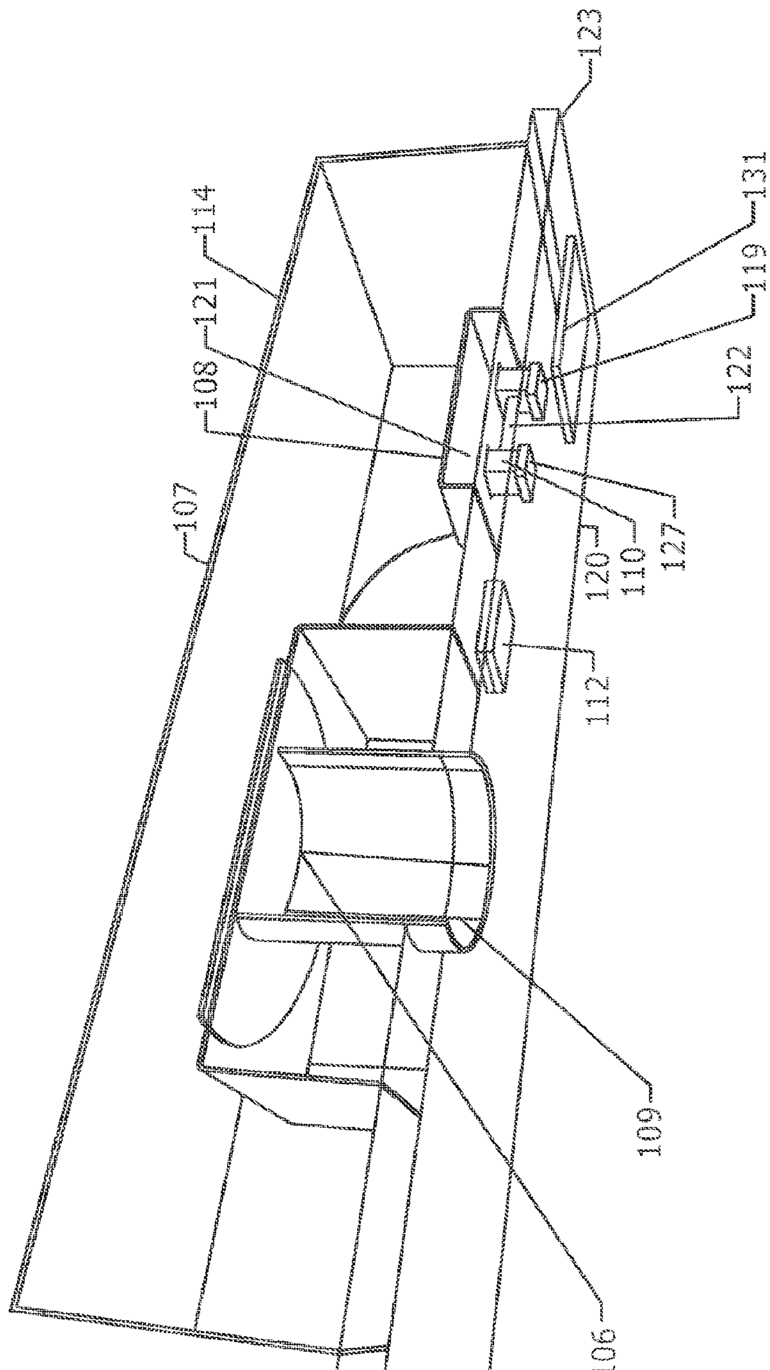


FIG. 1B

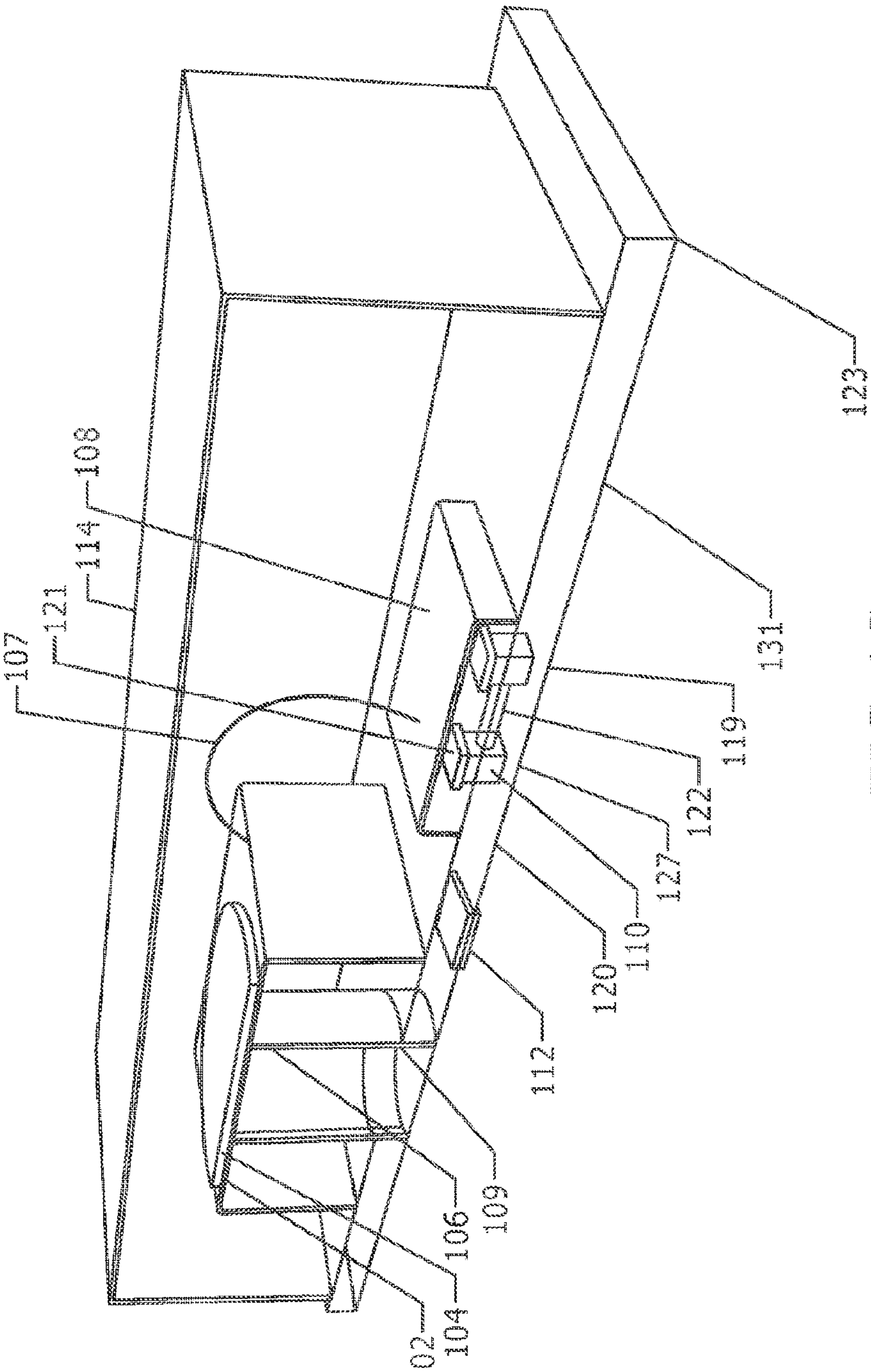


FIG. 1C

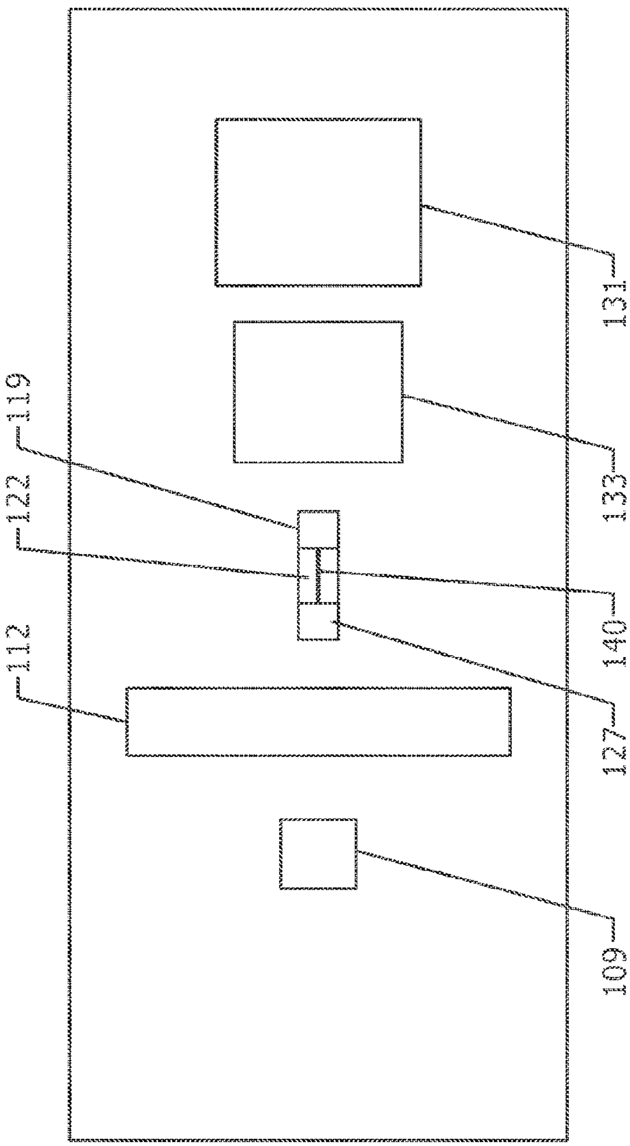


FIG. 2

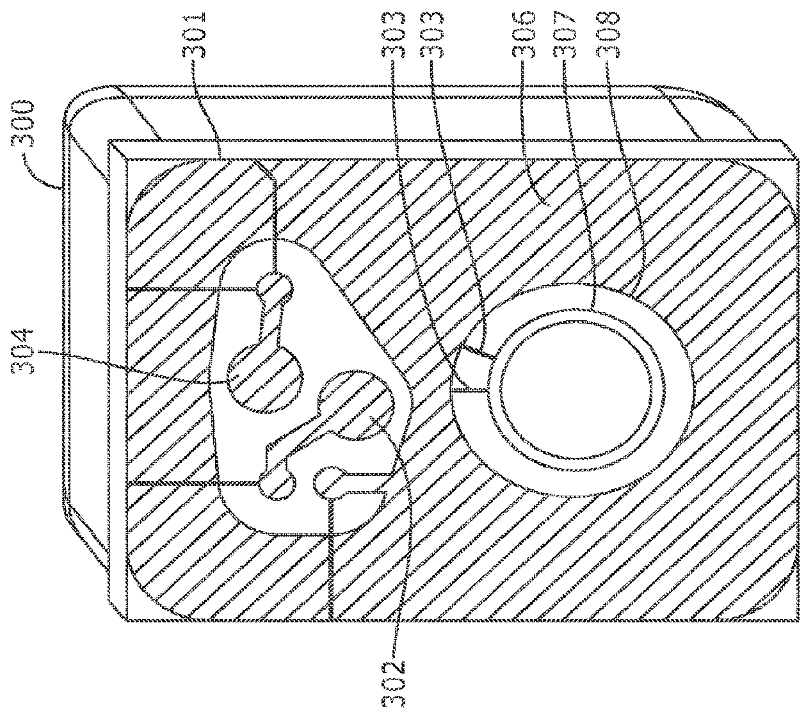


FIG. 3

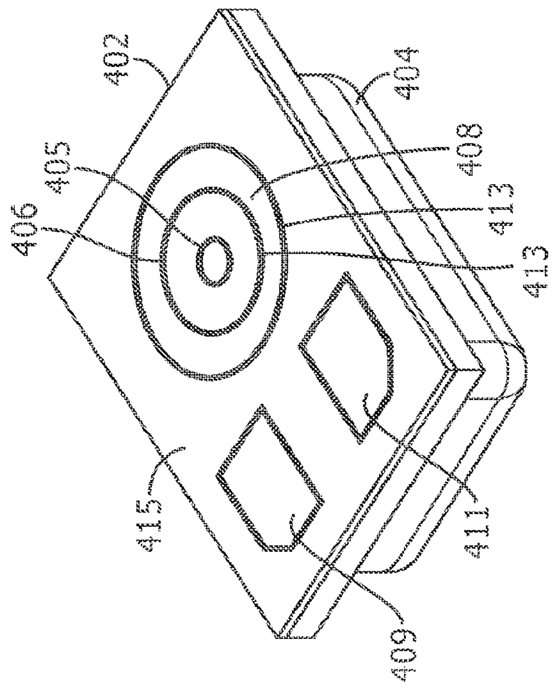


FIG. 5

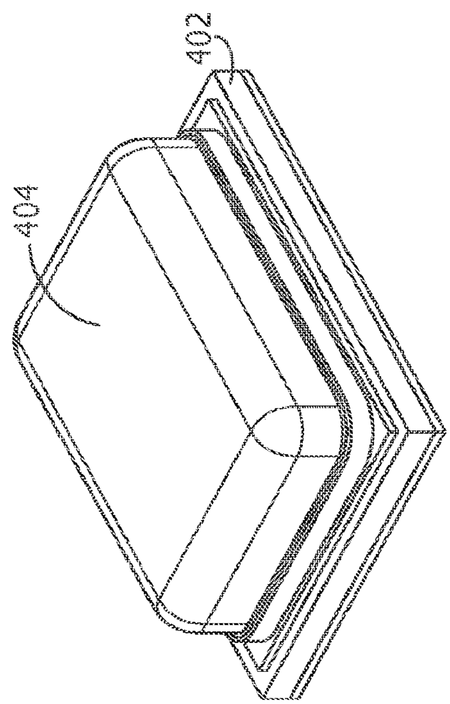


FIG. 4

VARISTOR IN BASE FOR MEMS MICROPHONES

CROSS REFERENCE TO RELATED APPLICATIONS

This patent claims benefit under 35 U.S.C. §119 (e) to United States Provisional Application No. 61835782 entitled "Varistor in Base for MEMS Microphones" filed Jun. 17, 2013, the content of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

This application relates to MicroElectroMechanicalSystem (MEMS) devices and, more specifically, to programming these devices.

BACKGROUND OF THE INVENTION

MicroElectroMechanical System (MEMS) devices include microphones and receivers to mention two examples. In these devices, different electrical components are disposed together within a housing unit. For example, a receiver typically includes a coil, magnets, and stack, among other components and these components are housed within the receiver assembly. Other types of acoustic devices may include other types of components.

Acoustic devices sometimes include integrated circuits such as application specific integrated circuit (ASICs). Often, these devices need to be programmed. Programming is typically accomplished by the use of external pads that are often located on the bottom of a MEMS device. These pads couple to the integrated circuit through conductive traces or other conductive members passing through the substrate. To program a device, a user usually couples a programming device to these pads, and then programs the integrated circuit. Once the programming is accomplished, the user simply removes the device.

There are some problems associated with these previous approaches. It is typically not desirable to allow the device to be re-programmed after the initial programming is accomplished. In this case, an unauthorized user might simply connect another programming device to the pads, and then reprogram the device. Unauthorized programming of an ASIC, for example, may cause the ASIC to function improperly and, in fact, may prevent the entire MEMS device from functioning properly. This, in turn, may have consequences that range from minor performance issues concerning the degradation of system performance to safety issues when the MEMS device is disposed in a critical piece of electronic equipment.

Previous systems and approaches have not provided a way to adequately prevent the unauthorized re-programming of integrated circuits in MEMS devices. In fact, previous systems and approaches are completely silent as to overcoming these problems.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the disclosure, reference should be made to the following detailed description and accompanying drawings wherein:

FIGS. **1**A, **1**B, and **1**C comprise diagrams of a MEMS device according to various embodiments of the present invention;

FIG. **2** comprises a block diagram of shorting the programming functionality of integrated circuits in MEMS devices according to various embodiments of the present invention;

FIG. **3** comprises a block diagram of a MEMS device according to various embodiments of the present invention;

FIG. **4** comprises a perspective view of a MEMS device according to various embodiments of the present invention; and

FIG. **5** comprises a perspective view of the bottom of a MEMS device according to various embodiments of the present invention.

Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity. It will further be appreciated that certain actions and/or steps may be described or depicted in a particular order of occurrence while those skilled in the art will understand that such specificity with respect to sequence is not actually required. It will also be understood that the terms and expressions used herein have the ordinary meaning as is accorded to such terms and expressions with respect to their corresponding respective areas of inquiry and study except where specific meanings have otherwise been set forth herein.

DETAILED DESCRIPTION

In the present approaches, electrical pads or regions are provided on the substrate of a MEMS device. One or more of the pads or regions is used for programming an integrated circuit. After the initial programming is accomplished, an anti-fuse region is fused (or in some way actuated), and this action provides a shorted connection between the programming pad to ground. Consequently, after initial programming is accomplished, the programming capability of the device is de-activated and cannot be re-activated. In so doing, unauthorized re-programming of the ASIC is prevented.

Referring now to FIG. **1**A, **1**B, **1**C and FIG. **2**, a MEMS microphone **100** is described. The MEMS microphone **100** includes a MEMS device **102** (including a diaphragm **104** and a back plate **106**). The MEMS microphone **102** is coupled by wires **107** to an application specific integrated circuit (ASIC) **108** and both are disposed on a substrate **123**. The device shown in FIGS. **1** and **2** is a bottom port microphone. However, it will be appreciated that the approaches described herein can be used with top port devices as well (i.e., a device where the port extends through the lid).

The ASIC **108** may provide a variety of functions such as voltage amplification. The ASIC **108** has a first connection **110** (e.g., a conductive trace or other conductor) between a first connector **114** on the ASIC **108** and a first pad **119** on a bottom surface of the substrate **123**. A second connector **121** on the ASIC **108** couples to a second connector **120** (e.g., a conductive trace or other conductor) and then to a ground plane **112**. The ground plane **112** is also coupled to a ground pad **127** on the bottom surface of the substrate **123**.

A power pad **131** is coupled to the ASIC **108** and allows power to be supplied to the ASIC **108**. An output pad **133** also couples to the ASIC **108** and allows the output of the ASIC **108** to be received by other electronic devices.

In operation, sound energy is received through a port **109**. The sound energy causes the diaphragm **104** to move, and this creates a change in electrical potential with the back plate **106**, thereby creating an electrical signal. The electrical signal is processed by the ASIC **108** and after processing may be sent to the output pad **133** on the bottom of the microphone **100** for use by other electronic equipment. For example, the microphone **100** may be disposed in an electronic device such as a cellular telephone or a personal computer. The microphone **100** may be disposed in other types of devices as well.

The bottom surface of the substrate **123** includes an anti-fuse region **122** that extends between the pad **119** and the pad **127**. The anti-fuse region may be a magnesium oxide varistor. Other materials may also be used. When being programmed, the anti-fuse region **122** is not fused and the pads **119** and **127** are electrically isolated and disconnected from each other. A programmer initially couples a programming device to the pad **119** and then programs the ASIC **108**.

In some aspects after the initial programming has been accomplished, the anti-fuse region **122** is shorted (e.g., by burning), creating an electrical short **140** (i.e., an electrical conduction path) between the first pads **119** and **127**. Consequently, future re-programming of the ASIC is impossible since the ASIC **108** is now shorted to ground.

Referring now to FIG. **3**, a MEMS arrangement seen by a user (e.g., a customer) is shown. It will be appreciated that the example of FIG. **3** is a top port device, but that the approaches described herein can also be used with bottom port devices. This arrangement shows a bottom surface **301** of a substrate of a microphone **300** and the electrical connections visible to the customer on the bottom surface **301** of the MEMS microphone **300**. The bottom surface **301** includes a power pad **302**, an output pad **304**, a ground region **306**, a programming pad **307**, and an anti-fuse (e.g., magnesium oxide varistor) region **308**. It will be appreciated that these electrical contact points are electrically coupled to various electronic devices such as the ASIC shown in FIG. **1**. For simplicity, the ASIC and electrical paths to the ASIC are not shown in FIG. **3**.

The power pad **302** electrically couples power to the ASIC. The output pad **304** is an output of the ASIC. A customer electronic device may couple to this pad. For example, the microphone **300** may be disposed in an electronic device such as a cellular telephone or a personal computer and electrical components of these devices may couple to the MEMS microphone. The microphone **300** may be disposed in other types of devices as well.

During initial programming, a customer couples a programming device to the programming pad **307**. This step may be accomplished at the manufacturing facility. However, in some situations it may be allowed to occur at a customer location. After the coupling of the programming device to the MEMS microphone **300** is accomplished, programming of the ASIC occurs. For example, various computer instructions, parameters, or values may be programmed in the ASIC using the programming pad **307** during the programming of the MEMS microphone **300**.

After the initial programming is accomplished, it is desired to eliminate the ability of future or unauthorized users to re-program the device. In these regards, shorts **303** are created between the ground region **306** and the programming pad **307**. The shorts **303** are conductive electrical paths.

More specifically, the ASIC also includes an anti-fuse region **305**. The anti-fuse region **308** is, for example, a magnesium oxide varistor (MOV) region. The MOV material is burned up by, for example, application of a high voltage to create paths **303** between the ground region **306** and the programming pad **307**. Consequently, after the initial programming is accomplished, future re-programming of the ASIC is impossible since the programming pins of the ASIC are now shorted to ground.

Referring now to FIGS. **4** and **5**, another example of a MEMS microphone is shown. The MEMS assembly **400** includes a substrate **402** and a cover **404**. The assembly **400** includes an ASIC disposed in the assembly and not shown. The substrate **402** includes a programming ring **406** and magnesium oxide varistor (MOV) region **408**. A port **405** extends through the substrate **402** into the interior of the assembly **400** allowing sound to enter the assembly. As shown, the device in FIG. **4** and FIG. **5** is a bottom port device. However, it will be appreciated that the approaches described herein can also be applied to top port devices.

The MOV region **408** is adjacent to a ground region **415**. During initial programming, a customer couples a programming device to the programming ring **406**. The programming ring **406** electrical couples to an ASIC (not shown in FIG. **4** or **5**). After coupling is accomplished, programming of the ASIC occurs. For example, various computer instructions, parameters and values may be programmed into the ASIC. The substrate **402** also includes an output pad **409** that couples to the ASIC providing an output for the ASIC. The substrate **402** additionally includes a power pad **411** that couples to the ASIC and allows power to be supplied to the ASIC.

After initial programming is accomplished, it is typically desired to eliminate the ability of an unauthorized user to re-program the ASIC. In these regards, a high voltage is applied to the MOV region **408**. The application of the high voltage creates one or more shorts **413** (conductive paths) between the programming ring **406** and the ground region **415**. Thus, the ASIC cannot be programmed because the programming ring **406** (which couples to a programming pin on the AISC) is now grounded.

Preferred embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. It should be understood that the illustrated embodiments are exemplary only, and should not be taken as limiting the scope of the invention.

What is claimed is:

1. A micro electro mechanical system (MEMS) apparatus, comprising:
- a substrate with a first surface and a second surface, the first surface and the second surface being on opposing sides of the substrate;
- a programming contact pad disposed on the second surface of the substrate;
- a MEMS device disposed on the first surface of the substrate;
- an integrated circuit disposed on the first surface of the substrate and electrically connected to the MEMS device and the programming contact pad;
- an anti-fuse region coupled to the programming contact pad and to ground;
- such that when the anti-fuse region is not fused a first electrical path exists from the programming contact pad to the integrated circuit;
- such that when the anti-fuse region is fused, a second electrical path is created from the programming contact pad to ground and the first electrical path is no longer available for programming purposes.

2. The MEMS apparatus of claim **1**, wherein the fusing is permanent.

3. The MEMS apparatus of claim **1**, wherein the integrated circuit is an application specific integrated circuit (ASIC) that performs voltage amplification.

4. The MEMS apparatus of claim **1**, wherein the fusing is performed by burning.

5. The MEMS apparatus of claim **1**, wherein the anti-fused region comprises a magnesium oxide varistor.

6. A method of programming micro electro mechanical system (MEMS) apparatus, the MEMS apparatus including a substrate with a first surface and a second surface, a programming contact pad disposed on the second surface of the substrate, the first surface and the second surface being on opposing sides of the substrate, and a MEMS device disposed on the first surface of the substrate and an integrated circuit disposed on the first surface of the substrate and connected to the MEMS device and the programming contact pad, and an anti-fuse region coupled to the programming contact pad and to ground, the method comprising:

initially programming the integrated circuit using a first electrical path that exists from the programming contact pad to the integrated circuit;

fusing the anti-fuse region such that when the anti-fuse region is fused, a second electrical path is created from the programming contact pad to ground and the first electrical path is no longer available for programming purposes.

7. The method of claim **6**, wherein the fusing is permanent.

8. The method of claim **6**, wherein the integrated circuit is an application specific integrated circuit (ASIC) that performs voltage amplification.

9. The method of claim **6**, wherein the fusing is performed by burning.

10. The method of claim **6**, wherein the anti-fused region comprises a magnesium oxide varistor.

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